PENDING CLAIMS

1. (Issued Patent) An apparatus for coding, storing or transmitting, and decoding M x M sized blocks of digitally represented images, where M is an even number, comprising

   a. a forward transform comprising

      i. a base transform having M channels numbered 0 through M-1, half of said channel numbers being odd and half being even;

      ii. an equal normalization factor in each of the M channels selected to be dyadic-rational;

      iii. a full-scale butterfly implemented as a series of lifting steps with a first set of dyadic rational coefficients;

      iv. M/2 delay lines in the odd numbered channels;

      v. a full-scale butterfly implemented as a series of lifting steps with said first set of dyadic rational coefficients; and

      vi. a series of lifting steps in the odd numbered channels with a second specifically selected set of dyadic-rational coefficients;

   b. means for transmission or storage of the transform output coefficients; and

   c. an inverse transform comprising

      i. M channels numbered 0 through M-1, half of said channel numbers being odd and half being even;

      ii. a series of inverse lifting steps in the odd numbered channels with said second set of specifically selected dyadic-rational coefficients;

iii. a full-scale butterfly implemented as a series of lifting steps with said first set of specifically selected dyadic-rational coefficients;

iv. M/2 delay lines in the even numbered channels;

v. a full-scale butterfly implemented as a series of lifting steps with said first set of specifically selected dyadic-rational coefficients;

vi. an equal denormalization factor in each of the M channels specifically selected to be dyadic-rational; and

vii. a base inverse transform having M channels numbered 0 through M-1.

2. (Issued Patent) The apparatus of Claim 1 in which the normalizing factor takes the value 25/16 and simultaneously the denormalizing factor takes the value 16/25.

3. (Issued Patent) The apparatus of Claim 1 in which the normalizing factor takes the value 5/4 and simultaneously the denormalizing factor takes the value 4/5.

4. (Issued Patent) The apparatus of Claim 1 in which the first set of dyadic rational coefficients are all equal to 1.

5. (Issued Patent) The apparatus of Claim 1 in which the second set of dyadic rational coefficients are all equal to ½.

6. (Issued Patent) The apparatus of Claim 1 in which the base transform is any M x M invertible matrix of the form of a linear phase filter and the inverse base transform is the inverse of said M x M invertible matrix.

7. (Issued Patent) The apparatus of Claim 1 in which the base transform is the forward M x M discrete cosine transform and the inverse base transform is the inverse M x M discrete cosine transform.

8. (Issued Patent) An apparatus for coding, compressing, storing or transmitting, and decoding a block of M x M intensities from a digital image selected by an M x M window moving recursively over the image, comprising:

   a. an M x M block transform comprising:

      i. an initial stage

      ii. a normalizing factor in each channel

   b. a cascade comprising a plurality of dyadic rational lifting transforms, each of said plurality of dyadic rational lifting transforms comprising

      i. a first bank of pairs of butterfly lifting steps with unitary coefficients between adjacent lines of said transform;

      ii. a bank of delay lines in a first group of M/2 alternating lines;

      iii. a second bank of butterfly lifting steps with unitary coefficients, and

      iv. a bank of pairs of butterfly lifting steps with coefficients of 1/2 between M/2 -1 pairs of said M/2 alternating lines;

   c. means for transmission or storage of the output coefficients of said M x M block transform; and

   d. an inverse transform comprising

      i. a cascade comprising a plurality of dyadic rational lifting transforms, each of said plurality of dyadic rational lifting transforms comprising

a) a bank of pairs of butterfly lifting steps with coefficients of 1/2 between said M/2 -1 pairs of said M/2 alternating lines;

b) a first bank of pairs of butterfly lifting steps with unitary coefficients between adjacent lines of said transform;

c) a bank of delay lines in a second group of M/2 alternating lines; and

d) a second bank of pairs of butterfly lifting steps with unitary coefficients between adjacent lines of said transform;

ii. a de-scaling bank; and

iii. an inverse initial stage.

9. (Issued Patent) A method of coding, storing or transmitting, and decoding M x M sized blocks of digitally represented images, where M is a power of 2, comprising

a. transmitting the original picture signals to a coder, which effects the steps of

i. converting the signals with a base transform having M channels numbered 0 through M-1, half of said channel numbers being odd and half being even;

ii. normalizing the output of the preceding step with a dyadic rational normalization factor in each of said M channels;

iii. processing the output of the preceding step through two lifting steps with a first set of identical dyadic rational coefficients connecting each pair of adjacent numbered channels in a butterfly configuration;

iv. transmitting the resulting coefficients through M/2 delay lines in the odd numbered channels;

v. processing the output of the preceding step through two inverse lifting steps with the first set of dyadic rational coefficients connecting each pair of adjacent numbered channels in a butterfly configuration; and

vi. applying two lifting steps with a second set of identical dyadic rational coefficients connecting each pair of adjacent odd numbered channels to the output of the preceding step;

b. transmitting or storing the transform output coefficients;

c. receiving the transform output coefficients in a decoder; and

d. processing the output coefficients in a decoder, comprising the steps of

i. receiving the coefficients in M channels numbered 0 through M-1, half of said channel numbers being odd and half being even;

ii. applying two inverse lifting steps with dyadic rational coefficients connecting each pair of adjacent odd numbered channels;

iii. applying two lifting steps with dyadic rational coefficients connecting each pair of adjacent numbered channels in a butterfly configuration;

iv. transmitting the result of the preceding step through M/2 delay lines in the even numbered channels;

v. applying two inverse lifting steps with dyadic rational coefficients connecting each pair of adjacent numbered channels in a butterfly configuration;

vi. denormalizing the result of the preceding step with a dyadic rational inverse normalization factor in each of said M channels; and

vii. processing the result of the preceding step through a base inverse transform having M channels numbered 0 through M-1.

10. (Issued Patent) A method of coding, compressing, storing or transmitting, and decoding a block of M x M intensities from a digital image selected by an M x M window moving recursively over the image, comprising the steps of:

a. Processing the intensities in an M x M block coder comprising the steps of:

   i. processing the intensities through an initial stage;

   ii. scaling the result of the preceding step in each channel;

b. processing the result of the preceding step through a cascade comprising a plurality of dyadic rational lifting transforms, each of said plurality of dyadic rational lifting transforms comprising

   i. a first bank of pairs of butterfly lifting steps with unitary coefficients between adjacent lines of said transform;

   ii. a bank of delay lines in a first group of M/2 alternating lines;

   iii. a second bank of butterfly lifting steps with unitary coefficients, and

   iv. a bank of pairs of butterfly lifting steps with coefficients of 1/2 between M/2 -1 pairs of said M/2 alternating lines;

c. transmitting or storing the output coefficients of said M x M block coder;

d. receiving the output coefficients in a decoder; and

e. processing the output coefficients in the decoder, comprising the steps of

i. processing the output coefficients through a cascade comprising a plurality of dyadic rational lifting transforms, each of said plurality of dyadic rational lifting transforms comprising

a) a bank of pairs of butterfly lifting steps with coefficients of 1/2 between said M/2 -1 pairs of said M/2 alternating lines;

b) a first bank of pairs of butterfly lifting steps with unitary coefficients between adjacent lines of said transform;

c) a bank of delay lines in a second group of M/2 alternating lines;

d) a second bank of pairs of butterfly lifting steps with unitary coefficients between adjacent lines of said transform;

e) a de-scaling bank; and

processing the results of the preceding step in an inverse initial stage.

11. (Issued Patent – currently being amended) The apparatus of Claim1 in which the ~~constants~~ <u>coefficients</u> are approximations chosen for rapid computing rather than exact ~~constants~~ <u>coefficients</u>.

12. <u>(Preliminary Amendment – currently being amended) A method of processing blocks of samples of digital signals of integer length M comprising processing the digital samples of length</u>

M with an invertible linear transform of dimension M, said transform being representable as a cascade, using the steps, in arbitrary order, of:

a) at least one +/-1 butterfly step,

b) at least one lifting step with rational complex coefficients, and

c) at least one scaling factor.

13. (Preliminary Amendment -- original) The method of Claim 12 additionally comprising the step of at least one time delay.

14. (Preliminary Amendment -- original) The method of claim 12, wherein the rational complex coefficients in the lifting steps are dyadic.

15. (Preliminary Amendment -- original) The method of claim 12, wherein

a) said invertible transform is an approximation of a biorthogonal transform;

b) said biorthogonal transformation comprises a representation as a cascade of at least one butterfly step, at least one orthogonal transform, and at least one scaling factor;

c) said at least one orthogonal transform comprising a cascade of

ii) at least one +/-1 butterfly step,

iii) at least one planar rotation, and

iv) at least one scaling factor;

d) said at least one planar rotation being represented by equivalent lifting steps and scale factors; and,

e) said approximation being obtained by replacing floating point coefficients in the lifting steps with rational coefficients.

16. (Preliminary Amendment -- original) The method of claim 15, wherein the coefficients of the lifting steps are chosen to be dyadic rational.

17. (Preliminary Amendment -- original) The method of claim 12, wherein the invertible transform is a unitary transform.

18. (Preliminary Amendment -- original) The method of claim 12, wherein

a) said invertible transform is an approximation of a unitary transform;

b) said approximation of the unitary transform comprises a representation of the unitary transform as a cascade of at least one butterfly step, at least one orthogonal transform, and at least one scale factor;

c) said at least one orthogonal transform being represented as a cascade of

(1) at least one +/-1 butterfly steps,

(2) at least one planar rotation, and

(3) at least one scaling factor;

d) said at least one planar rotation being represented by equivalent lifting steps and scale factors; and,

e) said approximation being derived by using approximate rational values for the coefficients in the lifting steps.

19. (Preliminary Amendment -- original) The method of claim 18, wherein the invertible transform is an approximation of a transform selected from the group of special unitary transforms: discrete cosine transform (DCT); discrete Fourier transform (DFT); discrete sine transform (DST).

20. (Preliminary Amendment -- original) The method of claim 18, wherein the coefficients of the lifting steps are dyadic rational.

21. (Preliminary Amendment -- original) The method of claim 18, wherein at least one of the following lifting steps is used, whose matrix representations take on the form:

$\begin{bmatrix} 1 & a \\ 0 & 1 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ b & 1 \end{bmatrix}$, where a, b are selected from the group:

+/- {8, 5, 4, 2, 1, ½, ¼, ¾, 5/4, 1/8, 3/8, 2/5, 5/8, 7/8,1/16, 3/16, 5/16, 7/16, 9/16, 11/16, 13/16, 15/16, 25/16}.

22. (Preliminary Amendment -- original) The method of claim 21, wherein the invertible transform is an approximation of a transform selected from the group of special unitary transforms: discrete cosine transform (DCT); discrete Fourier transform (DFT); discrete sine transform (DST).

23. (Preliminary Amendment -- original) The method of claim 22, wherein the approximation of the 4-pt DCT is selected from the group of matrices:

$$\underline{\left\{\begin{bmatrix}1 & 1 & 1 & 1\\ 2 & 1 & -1 & -2\\ 1 & -1 & -1 & 1\\ 1 & -1 & 1 & -1\end{bmatrix}, \begin{bmatrix}1 & 1 & 1 & 1\\ 2 & 1 & -1 & -2\\ 1 & -1 & -1 & 1\\ 1 & -2 & 2 & -1\end{bmatrix}, \begin{bmatrix}1 & 1 & 1 & 1\\ 2 & 1 & -1 & -2\\ 1 & -1 & -1 & 1\\ 5 & -2 & 2 & -5\end{bmatrix}\right\}}$$

24. (Amended) The method of Claim 19 in which the invertible transform is an approximation of a transform selected from the group three point DCT, 4 point DCT, 8 point DCT, and 16 point DCT.

25. (Amended) The method of Claim 19 in which the invertible transform is an approximation of a transform selected from the group 512 point FFT, 1024 point FFT, 2048 point FFT, and 4096 point FFT.